An Evaluation Method of Comprehensive Ability for Professional Degree Postgraduates with AHP and EWM*

Shaowei Pan[a *], Bo Yang[b] and Qian Song[c]

[a]dennis_pan@163.com, [b]2446317515@qq.com, [c]1659809500@qq.com

School of Computer Science, Xi'an Shiyou University, Shaanxi, 710065, China

Abstract—In order to evaluate the comprehensive ability of professional degree postgraduates comprehensively and objectively, and further improve their educational quality, an evaluation method of comprehensive ability based on the existing analytic hierarchy process (AHP) and entropy weight method (EWM) is proposed in this paper. Firstly, the evaluation index system of comprehensive ability for professional degree postgraduates is constructed. Secondly, the weight of each index is calculated by AHP and EWM, respectively. On this basis, the comprehensive weight of each index is calculated by weighting method. Finally, according to the comprehensive weight and the score of each index, the scores of comprehensive ability for professional degree postgraduates are obtained by weighted summation. The method in this paper is applied to the comprehensive ability evaluation of 10 professional degree postgraduates from the School of Computer Science of Xi'an Shiyou University, and the evaluation results are very consistent with the actual situation. It can be seen that the evaluation method of comprehensive ability for professional degree postgraduates proposed in this paper has strong application value and popularization value.

Keywords—comprehensive ability, AHP, EWM, evaluation index, weighted summation

1. Introduction

In recent years, with the expansion of China's postgraduate enrolment scale, the quality of postgraduate education has become increasingly important [1] [2]. Therefore, evaluating the comprehensive ability of postgraduate students thoroughly and objectively and improving the postgraduate education quality on this basis have become urgent problems in China's colleges and universities. Postgraduate students' comprehensive ability is the core to evaluating the quality of postgraduate education and also an important testing standard [3]. However, the existing methods for evaluating postgraduate comprehensive ability often have strong limitations. Specifically, these evaluation methods only consider the evaluation of academic ability and ignore the evaluation of other abilities, such as practical and innovative abilities. Moreover, there are several problems, such as the use of a single evaluation index and a subjective evaluation method. At this time, it is highly important to construct a comprehensive,

IEDM 2024, February 23-25, Kuala Lumpur, Malaysia

DOI 10.4108/eai.23-2-2024.2345957

objective and scientific method for evaluating postgraduate comprehensive ability. In view of the above background, by combining the existing analytic hierarchy process and entropy weight method (AHP-EWM), this paper proposes a comprehensive ability evaluation method for professional degree postgraduates that can be used to achieve thorough and objective evaluation.

2. Method for evaluating the comprehensive ability of professional degree postgraduates with the AHP-EWM

2.1 Analytic Hierarchy Process

The analytic hierarchy process (AHP) was formally proposed by the American operations research scientist T.L. Saaty in the early 1970s. It is a systematic and hierarchical analysis method that combines qualitative and quantitative methods [4] [5]. The AHP decomposes a decision problem into different hierarchical structures according to the order of the overall goal, subgoal of each level, evaluation criteria and specific backup plan. Then, the method of solving the eigenvector of the judgement matrix is used to obtain the priority weight of each element at each level to an element at the upper level. Finally, the weighted sum method is used to hierarchically merge the final weight of each alternative plan to the overall goal. The AHP has been widely used in safe science and environmental science [6] [7].

2.2 Entropy weight method

The entropy weight method (EWM) is used for comprehensively evaluating multiple indexes. The importance of indexes is determined, and corresponding weights are assigned based on the concept of information entropy. This method can mine the inherent laws and information of the original data, and the weights obtained do not depend on evaluator experience, increasing the objectivity of the evaluation results. In general, the smaller the information entropy of an index is, the more information it can provide, the greater its role in evaluation and the greater its weight. In contrast, the greater the entropy of the information is, the smaller its weight.

2.3 Implementation process of the evaluation method of comprehensive ability for professional degree postgraduates

The implementation process of the evaluation method of comprehensive ability for professional degree postgraduates with the AHP-EWM[8] [9] [10] [11] [12] [13] [14] [15]is shown in Fig. 1. The process involves the following steps.

- The evaluation index system for the comprehensive ability of professional degree postgraduates is established, including the general target G, the first-level indexes P_1, P_2, and P_n, and the secondary indexes Q_1, Q_2, and Q_n.
- The AHP weight $w_i^{'}$ and EWM weight $w_i^{''}$ of each index are calculated by the AHP and EWM, respectively.

- Combined with the weight $w_i^{'}$ of the AHP and weight $w_i^{''}$ of the EWM, the comprehensive weight w_i of each index is calculated by the weighting method.
- According to the comprehensive weight w_i of each index, combined with the scores of each index, the comprehensive ability score of the postgraduates is obtained through weighted summation.

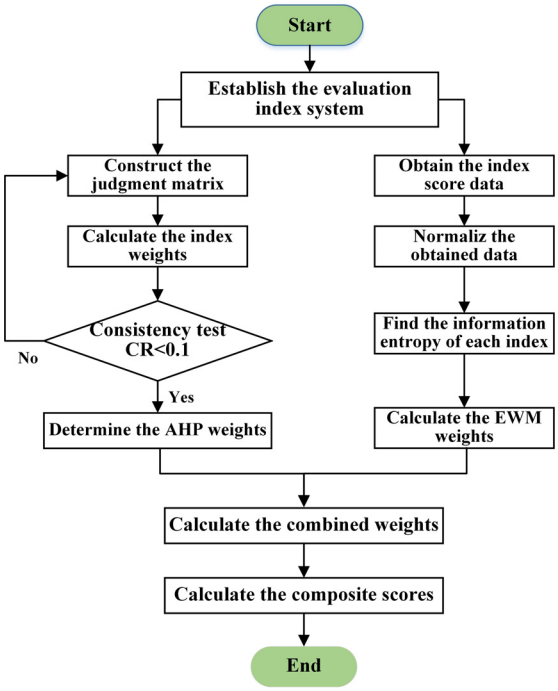

Fig. 1. Execution flow chart of the AHP-EWM.

3. Experiment and discussion

3.1 Data collection

A questionnaire survey, field investigation and interview methods were used to collect the academic results, academic achievements, research project experience, internship information, participation in discipline competitions and extracurricular activities of 10 postgraduate students at the School of Computer Science of the Xi'an Shiyou University, forming the original dataset for this study (Table 1 and Table 2).

3.2 Establishing an evaluation index system of comprehensive ability

According to the cultivation plan for professional degree postgraduates and considering enforceability, an evaluation index system of comprehensive ability for the professional degree postgraduates is constructed with 4 first-level indexes, namely, academic ability, practical ability, innovative ability and professional quality, and 18 second-level indexes, namely, academic performance and academic achievement [16], as shown in Fig. 2. The 18 indexes selected in the evaluation index system have a low correlation, which can effectively reduce index redundancy.

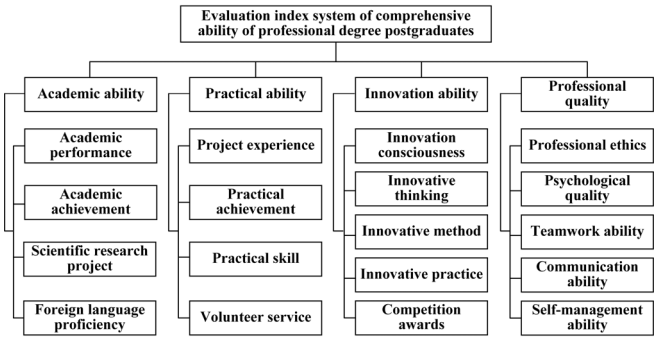

Fig. 2. Evaluation index system of comprehensive ability of professional degree postgraduates

Table 1. Score Of Academic ability and Practical ability

Sort	Academic ability				Practical ability			
	Academic performance	*Academic achievement*	*Scientific research project*	*Foreign language proficiency*	*Project experience*	*Practical achievement*	*Practical skill*	*Volunteer service*
A	88	96	89	90	92	90	85	90
B	90	90	92	86	96	88	86	93
C	92	96	88	96	90	92	96	85
D	88	90	90	92	90	96	90	80
E	80	80	80	88	88	80	90	85
F	80	85	75	80	70	70	75	78
G	80	70	75	82	85	70	80	80
H	67	75	65	75	80	60	65	70
I	70	60	80	60	60	90	66	60
J	60	70	60	70	60	60	70	72

Table 2. Score Of Innovation ability and Professional quality

Sort	Innovation ability					Professional quality				
	Innovation consciousness	*Innovative thinking*	*Innovative method*	*Innovative practice*	*Competition awards*	*Professional ethics*	*Psychological quality*	*Teamwork ability*	*Communication ability*	*Self-management ability*
A	86	90	90	92	96	87	90	92	90	88
B	90	92	95	92	94	89	92	85	92	93
C	85	89	85	89	80	90	90	88	90	90

D	90	90	90	90	92	88	88	88	88	86
E	80	88	88	88	85	80	88	82	80	86
F	78	85	78	80	77	80	88	80	75	85
G	76	85	79	80	75	80	88	80	75	75
H	70	60	60	65	60	65	70	66	68	65
I	65	60	70	60	70	80	80	80	85	86
J	60	70	60	70	60	60	85	85	60	60

3.3 Index weight calculation based on the AHP

1) Construction of the judgement matrix: The core objective of the AHP is to calculate the feature vector of the judgement matrix. After establishing the hierarchical structure system, the indexes or factors of each layer are compared in pairs according to the relative importance degree, and the mathematical judgement matrix is constructed by numerical quantization according to the 1-9 importance scale proposed by Professor T.L. Satty [17].

2) Calculation of the weights: The eigenvector represents the weight of the influence of each index at this level on the index at the previous level. Therefore, to obtain the weight, the maximum characteristic root $\lambda_{\max}$ and eigenvector of the judgement matrix should be calculated first, and the consistency test of the judgement matrix should be carried out [18]. If the test is passed, the eigenvector W corresponding to the largest characteristic root $\lambda_{\max}$ is normalized to the desired index weight. The calculation formula is shown in Formula (1):

$$XW = \lambda_{\max} W \tag{1}$$

In the above formula, X is the judgement matrix, $\lambda_{\max}$ is the eigenvalue of the judgement matrix X, and W is the eigenvector corresponding to the eigenvalue.

3) Consistency test of the judgement matrix: The purpose of consistency test is to evaluate the consistency level of the judgement matrix to ensure that the resulting weights are reliable. The AHP uses consistency indexes to evaluate whether the judgement matrix is consistent. The specific steps for calculating the consistency test indexes CI and CR are as follows:

Firstly, the consistency evaluation indexes CI is calculated, and the calculation formula is shown in Formula (2):

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

In the above formula, $\lambda_{\max}$ is the maximum characteristic root, and n is the judgement matrix order.

Secondly, the table of standardized values of RI order is queried according to the matrix order, and CI and RI are compared to derive the test coefficient CR, which is calculated as shown in Formula (3):

$$CR = \frac{CI}{RI} \tag{3}$$

where CI is a consistency index and RI is a random consistency index. When CR<0.1, the judgement matrix passes the consistency test, indicating that the consistency of the matrix is

good. Otherwise, the judgement matrix is considered to not pass the consistency test. The values in the judgement matrix need to be adjusted, and the consistency test needs to be performed again.

4) Determination of the index weights in each layer: After the consistency test is passed, the corresponding weights of each index can be obtained by normalizing the eigenvectors corresponding to $\lambda_{\max}$. The combined weight vector refers to the weight coefficient of the importance of indexes at each level relative to the overall goal. The weight calculation formula of the secondary indexes relative to the overall goal is shown in Formula (4):

$$w_i^{'} = w_p \cdot w_q \tag{4}$$

where $w_i^{'}$ is the weight of the second-level index relative to the total target, w_p is the weight of the first-level index, and w_q is the weight of the second-level index under the first-level index.

3.4 Determination of index weights with the EWM

1)Data normalization:

$$Y_{ij} = \frac{x_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \tag{5}$$

In the above formula, Y_{ij} is the value assigned to the i index of the normalized index assignment matrix by the j index, x_{ij} is the value assigned to the i index of the index assignment matrix by the j index, and X_i is the vector of the i index of the index assignment matrix.

2)Calculation of the information entropy of each index:

$$E_i = -\ln(n)^{-1} \sum_{i=1}^{n} \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \ln \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \tag{6}$$

In the above formula, E_i is the information entropy of the i index, and n is the number of evaluation indices.

3)Weight calculation of the entropy weight method:

$$w_i^{''} = \frac{1 - E_i}{\sum_{i=1}^{n} 1 - E_i} \tag{7}$$

In the above formula, $w_i^{''}$ is the weight of the i index calculated by the entropy weight method.

3.5 Determination of comprehensive weights

The following weighted method is used to calculate the comprehensive weight:

$$w_i = \frac{w_i^{'} w_i^{''}}{\sum_{i=1}^{n} w_i^{'} w_i^{''}} \tag{8}$$

In the above formula, w_i is the comprehensive weight value of the i index. The comprehensive weight value of each index obtained through calculation are shown in Table 3and Table 4.

Table 3. First part of the Comprehensive Weights Of Indexes

	Academic performance	***Academic achievement***	***Scientific research project***	***Foreign language proficiency***	***Project experience***	***Practical achievement***	***Practical skill***	***Volunteer service***
AHP weight	0.0325	0.0127	0.0325	0.0057	0.1302	0.1302	0.1302	0.0260
EWM weight	0.0494	0.0516	0.0511	0.0427	0.0713	0.0804	0.0782	0.0432
Comprehensive weight	0.0237	0.0097	0.0245	0.0036	0.1371	0.1547	0.1504	0.0166

Table 4. second part of the Comprehensive Weights Of Indexes

	Innovation consciousness	***Innovative thinking***	***Innovative method***	***Innovative practice***	***Competition awards***	***Professional ethics***	***Psychological quality***	***Team work ability***	***Communication ability***	***Self-management ability***
AHP weight	0.0365	0.0365	0.0365	0.0985	0.2087	0.0093	0.0093	0.0093	0.0093	0.0463
EWM weight	0.0530	0.0686	0.0728	0.0542	0.0785	0.0456	0.0326	0.0339	0.0458	0.0471
Comprehensive weight	0.0286	0.0370	0.0393	0.0789	0.2420	0.0063	0.0045	0.0047	0.0063	0.0322

3.6 Comprehensive evaluation results and discussion of professional degree postgraduates

According to the comprehensive weights of the above evaluation indexes, combined with the scores of professional degree postgraduates, the comprehensive ability score of professional degree postgraduates can be obtained via weighted summation. The calculation is shown in Formula (9).

$$s_j = \sum_{i,j=1}^{n} w_i s_{ji} \tag{9}$$

In the above formula, s_j is the comprehensive score of the j evaluated object, w_i is the comprehensive weight of the i index, and s_{ji} is the score of the j evaluated object in the i index.

Combined with the comprehensive performance information of the 10 professional degree postgraduates in Table 1 and Table 2, Formula (9) was used to score them, and their comprehensive results were obtained and sorted, as shown in Table 5. In Table 5, the top three postgraduates are Graduates B, D and A. Compared with Table 1 and Table 2, in addition to their strong academic ability, these three postgraduates also have excellent performance in terms of practical ability, innovative ability and professional quality. The overall ranking of graduate J is the lowest because this postgraduate not only has poor academic ability but also has poor performance in three aspects: practical ability, innovative ability and professional quality. In Table 1 and Table 2, postgraduate C has the strongest academic ability, but his comprehensive performance is not the highest because his innovative ability is weak. Table 5 shows that, in addition to academic ability, practical ability, innovative ability and professional quality also have a great impact on the comprehensive ability evaluation of professional degree postgraduates in the current training plan for professional degree postgraduates, which corresponds with the existing training spirit of the Ministry of Education for professional degree postgraduates. The comprehensive ability evaluation method proposed in this paper is reasonable and effective and has strong operability and feasibility.

Table 5. Comprehensive Scores And Ranking

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
Comprehensive score	90.94	91.49	88.33	91.04	85.41	75.72	77.60	65.15	70.54	63.23
Rank	3	1	4	2	5	7	6	9	8	10

4. Conclusion

Based on the existing AHP and EWM, this paper proposes an evaluation method for the comprehensive ability of professional degree postgraduates based on four first-level indices and eighteen second-level indices. The method proposed in this paper can achieve a reasonable and effective evaluation of the comprehensive ability of professional degree postgraduates. However, in practical application, the method still needs to be continuously optimized and perfected.

The method proposed in this paper has important reference significance for evaluating the personal ability of employees in enterprises, classifying reservoirs in the petroleum industry and evaluating the throughput of ports in transportation.

Acknowledgment. This paper is supported by the Research and Practice Project of Comprehensive Reform for Postgraduate Education of Xi'an Shiyou University (2023-X-YJG-014).

References

[1] Z. Zhang and B. Liu, “Innovative Education for postgraduates in the Era of Knowledge Economy”, Journal of Yangtze University (Social Science Edition), vol. 37, pp. 144–146, December 2014.

[2] J. Zhu and L. Wang, “On the components and strategies of core competence of graduate students”, Journal of Hebei University of Science and Technology (Social Science Edition), vol. 19, pp. 97–102, September 2019.
[3] J. Dong, “Research on Training and Improving the comprehensive ability of postgraduate practice and Planning Innovation”, Education and Teaching Forum, vol. 14, pp. 170–174, September 2023.
[4] J. Zhu, Research and application of Analytic Hierarchy Process. Shenyang City, Liaoning Province: Northeastern University, 2005.
[5] R. D. F. S. M. Russo and R. Camanho, “Criteria in AHP: A Systematic Review of Literature”, Procedia Computer Science, vol. 55, pp. 1123–1132, July 2015.
[6] A. Darko, A. P. C. Chan, E. E. Ameyaw, E. K. Owusu, E. Paern and D. J. Edwards, “Review of application of analytic hierarchy process (AHP) in construction”, International Journal of Construction Management, vol. 19, pp. 436–452, May 2018..
[7] V. Podvezko, Application of AHP Technique. LT Vilnius: Vilnius Gediminas Technical University, 2009.
[8] J. Wang, J. Jiao, H. Li, J. Gong, X. Li, Z. He and X. Sun, “Smart oil depot maturity assessment using the AHP-EWM fuzzy comprehensive evaluation model”, Petroleum and New Energy, vol. 36, pp. 1–7, February 2024.
[9] F. Gao, J. Yan, J. Wang, G. Luo, J. Jie, Y. Liu and J. He, “Evaluation method for wind turbine gearbox health based on AHP-EWM weight and fuzzy evaluation”, Machine Tool & Hydraulics, vol. 52, pp. 1–14, February 2024.
[10] Y. Fu, T. Zhou, Q. Xu, C. Yang, J. Zhang and C. Xiao, “Optimization of fresh-cutting method of gastrodia elata blume based on Entropy Weight Method and AHP”, Chinese Traditional and Herbal Drugs, vol. 55, pp. 1–10, February 2024.
[11] Y. Nie, Y. Li, Q. Liu, Q. He and X. Wen, “Safety evaluation of the liquid ammonia storage tank based on AHP-entropy weight method”, Industrial Safety and Environmental Protection, vol. 50, pp. 36–39 & 44, February 2024.
[12] B. Song, J. Liu, W. Yin, X. Zhang and X. Huang, “Evaluation of water environment improvement in Yinxi Plain River network area based on AHP-entropy Weight Method”, Water Resources and Power, vol. 42, pp. 68–72, March 2024.
[13] G. Cao, Q. Zhang, Z. Lu and Z. Liu, “Analysis of grinding conditions of cement combined grinding based on combined weights of Entropy and AHP method”, 42nd Chinese Control Conference, pp. 2592–2597, July 2023.
[14] J. Cheng, “Medical equipment index optimization and evaluation based on Analytic Hierarchy Process and entropy weight method”, China Medical Devices, vol. 38, pp. 137–143 & 157, December 2023.
[15] Q. Shi, H. Wang and H. Lu, “Research and Application of AHP-EWM-based Comprehensive Evaluation of Data Quality”, Proceedings of the 4th International Conference on Computer Science and Application Engineering, pp. 1-5, October 2020.
[16] W. Shi, Y. Tan and Z. Xiong, “Cultivation and promotion of comprehensive practical ability of full-time professional degree postgraduates”, Light Industry Science and Technology, vol. 37, pp. 167–168 & 170, June 2021.
[17] M. Chu, Construction of judgment matrix in Analytic Hierarchy Process. Nanjing City, Jiangsu Province: Nanjing University of Science and Technology, 2005.

[18] X. Deng, J. Li, H. Zeng, J. Chen and J. Zhao, “Analysis and Application of Weight Calculation Method of Analytic Hierarchy Process”, Journal of Mathematics in Practice and Theory, vol. 42, pp. 93–100, April 2012.